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Comprehensive Analysis of the Taxonomic Composition, Spatial Distribution, and Seasonal Dynamics of the Tomato (*Solanum lycopersicum* L.) Agroecosystem Entomofauna in Khorezm Region

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ABSTRACT

This study presents a comprehensive and systematic analysis of the entomofauna in tomato (*Solanum lycopersicum* L.) agroecosystems within the Khorezm region of Uzbekistan, characterized by a highly continental and arid climate. Field research was conducted during the 2023–2025 growing seasons in the open fields of "Davlat Rahmatulla" and "Yakubboy Zarifboy" farms in Urganch district. A total of 28 insect species belonging to 9 orders, 15 families, and 25 genera were identified. Taxonomic composition revealed that *Hemiptera* (28.6%, 8 species), *Lepidoptera* (17.9%, 5 species), and *Orthoptera* (17.9%, 5 species) were the most dominant orders. Dominance structure analysis based on the Pesenko index identified *Aphis gossypii*, *Bemisia tabaci*, and *Helicoverpa armigera* as dominant pests. Spatial and organ-specific distribution analysis showed that phytophagous pests actively inhabit foliage and fruits, whereas beneficial predators and parasitoids concentrate in leaf layers with high pest densities. Seasonal population dynamics were highly correlated with environmental factors, peaking during July–August when ambient temperatures ranged between 28°C and 35°C. Based on the ecological and population dynamics data, the optimal window for the implementation of Integrated Pest Management (IPM) strategies was identified as the second half of May and early June.

Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most widely cultivated and economically profitable vegetable crops worldwide, including in the agriculture of Uzbekistan (Singh & Sharma, 2019; Statistics Agency, 2023). However, one of the most serious factors limiting its yield and fruit quality is the complex of phytophagous insects that form in the agrobiocenosis. Under the conditions of global climate change, sharp shifts are occurring in the bioecological characteristics of pests, their distribution areas, and seasonal development dynamics. This necessitates regular monitoring of the taxonomic composition of the entomofauna in the tomato agroecosystem and the optimization of modern pest control systems (Rahimov *et al.,* 2021).

The Khorezm region, located in the north-western part of Uzbekistan, is distinguished by its highly continental, hot, and arid climate. This extreme climatic condition creates a favorable ecological basis for the rapid reproduction and massive damage of a number of sucking and chewing pests in the tomato agroecosystem, especially aphids (*Aphididae*), whiteflies (*Aleyrodidae*), thrips (*Thripidae*), and noctuid moths (*Noctuidae*) (Sharma *et al.,* 2020; Zhang *et al.,* 2022).

An agrobiocenosis is a complex system in which not only pests but also beneficial entomophages (e.g., ladybugs, lacewings) and parasitoids (e.g., braconids) that naturally control their numbers operate. Therefore, to develop an environmentally safe and biologically highly effective Integrated Pest Management (IPM) system, studying the species composition of all beneficial and harmful insects in this agroecosystem, the spatial distribution of species across plant organs, and their seasonal developmental dynamics is an extremely urgent task (Rahimov *et al.,* 2021). The main objective of this study is to comprehensively analyze the entomofauna of the open-field tomato agrobiocenosis under the conditions of the Khorezm region, identify dominant and subdominant species, study the patterns of spatial and organ-specific distribution of insects, and evaluate the impact of climatic factors on their seasonal activity to scientifically determine ecologically based pest control periods.

Materials and Methods

Natural-geographical conditions of the study area

The research was conducted during 2023-2025 in the Urgench district of the Khorezm region. The Khorezm region is located in the north-west of Uzbekistan, in the lower reaches of the Amu Darya River, and is characterized by a highly continental climate, hot and dry summer months, and low precipitation. The soil conditions in the experimental fields mainly consist of meadow-alluvial and saline soils.

Sample collection and entomological observations

Field observations were conducted in the open agroecosystems of two large farms in the Urgench district:

“Davlat Rahmatulla” farm tomato fields.
“Yakubboy Zarifboy” farm tomato fields.

Generally accepted classical entomological and agroecological methodologies were used to collect the entomofauna and record their numbers:

Sucking and small insects (aphids, whiteflies, thrips): 50 plants were selected from each field using the diagonal method, and a direct counting method was applied from the lower, middle, and upper layers of the leaves.

Flying and large insects: Samples were collected using a special entomological net (by sweeping 100 times regularly).

Soil-dwelling species (soil and root zone fauna): Identified using Barber traps (formalin cups) and the soil excavation method.

Lepidoptera representatives (noctuid moths and their larvae): Identified by visual inspection and photo-documentation of tomato plant parts, stems, and fruits, and segregated into species in the laboratory.

Ecological and statistical calculations

A. Zaime and J. Y. Gautier's (1989) formula was used to evaluate the overall population density dynamics of the species:

$$Ar(\%) = 100 \times \frac{Ni}{N}$$

Where:

Ni– total number of observed species,
N – absolute number of all observed species.

The density indicators of species were divided into the following four groups:

Very abundant: Ar ≤ 10%
Sufficiently abundant: 5 ≤ A r< 10%
Abundant: 1 ≤ Ar < 5%
Rare: Ar < 1%

The assessment of the dominance level of species was carried out according to Pesenko's (1982) methodology.

By calculating the occurrence frequency and share of each species in the total entomofauna, the species were divided into *Dominant, Subdominant*, and *Rare (accidental)* groups.

Results and Discussion

Taxonomic and systematic composition of the tomato agroecosystem entomofauna

As a result of comprehensive studies conducted in the tomato agroecosystems of the Khorezm region during 2023–2025, a total of 28 insect species belonging to 9 orders, 15 families, and 25 genera were identified.

According to the results of the systematic analysis, the largest portion of species belongs to the order *Hemiptera* (28.6%), which are mainly manifested as a complex of sucking pests (aphids, whiteflies, bugs) in the agroecosystem. The orders *Lepidoptera* and *Orthoptera* occupy a share of 17.9% each (with 5 species respectively).

The main part of the beneficial insects corresponds to the orders *Coleoptera* (ladybugs), *Neuroptera* (lacewings), *Hymenoptera* (parasitoid wasps), and *Diptera*.

Spatial and organ-specific distribution of insects across the agroecosystem

Although the general composition of insects was similar in the research fields of the “Davlat Rahmatulla” and “Yakubboy Zarifboy” farms, their population densities differed slightly according to agrotechnical conditions. While sucking pests formed a high density in the “Davlat Rahmatulla” farm, it was found that the proportion of natural entomophages was higher in the fields of the “Yakubboy Zarifboy” farm, resulting in a more active self-regulation system within the agrobiocenosis.

This distribution is explained by the feeding characteristics (trophic interactions) of the insects. Sucking pests (*Hemiptera, Thysanoptera*) predominantly gather on the underside of the leaf blade. *Lepidoptera* representatives (*Helicoverpa armigera, Agrotis segetum*) cause the greatest damage to fruits and flowering organs during the vegetation period. It was identified that *Orthoptera* representatives primarily cause damage in the root and near-soil layers (at the root collar).

Dominance and ecological structure of the entomofauna

Species were distributed into dominance groups according to Pesenko's methodology. The obtained results serve as a very important ecological indicator in evaluating the stability of the tomato agroecosystem (Table 3.4).

According to the research results, it was proven that the three main species forming the dominant group in the tomato agroecosystem (*Aphis gossypii, Bemisia tabaci*, and *Helicoverpa armigera*) produce the highest population during the vegetation period, constituting the primary economic damage factors for tomato crops.

The subdominant group includes both sucking phytophages and their natural enemies beneficial entomophages such as *Coccinella septempunctata, Hippodamia variegata*, and *Chrysoperla carnea*. This situation indicates that a natural trophic chain is well-formed in the agroecosystem and biological control capabilities exist.

Ecological-functional groups of insects

Based on their trophic and ecological functions, the identified entomofauna was divided into 4 main ecological groups:

1. Sucking phytophages feeding on leaf and stem sap: *Aphis gossypii, Myzus persicae, Bemisia tabaci, Trialeurodes vaporariorum, Thrips tabaci*. This group reduces the plant's photosynthetic function and spreads viral diseases.

2. Chewing phytophages damaging generative and vegetative organs: *Helicoverpa armigera, Agrotis segetum, Autographa gamma, Heliothis viriplaca*. This group directly damages tomato yield and its marketable quality.

3. Pests causing damage in the root and soil layers: *Gryllotalpa gryllotalpa*, grasshoppers (*Orthoptera* representatives). They mainly lead to the death of seedlings in the early stages of vegetation.

4. Complex of beneficial entomophages and parasitoids: Predatory beetles (*Coccinella septempunctata, Hippodamia variegata*), lacewings (*Chrysoperla carnea*), hoverflies (*Episyrphus balteatus*), parasitic wasps (*Bracon hebetor, Campoletis chlorideae*), and mantises. This beneficial group performs a vital ecological function by keeping the phytophage population below the Economic Threshold Level (ETL).

Table.1 Systematic composition of the tomato agroecosystem entomofauna

№	Order (Ordo)	Family (Familia)	Genus (Genus)	Species (Species)
1	*Coleoptera*	*Chrysomelidae*	*Leptinotarsa*	*Leptinotarsa decemlineata*
		Coccinellidae	*Coccinella*	*Coccinella septempunctata*
			Hippodamia	*Hippodamia variegata*
		Carabidae	*Harpalus*	*Harpalus rufipes*
2	*Lepidoptera*	*Noctuidae*	*Helicoverpa*	*Helicoverpa armigera*
			Agrotis	*Agrotis segetum*
			Agrotis	*Agrotis exclamationis*
			Autographa	*Autographa gamma*
			Heliothis	*Heliothis viriplaca*
3	*Hemiptera*	*Aphididae*	*Aphis*	*Aphis gossypii*
			Myzus	*Myzus persicae*
			Aphis	*Aphis craccivora*
		Miridae	*Lygus*	*Lygus pratensis*
			Lygus	*Lygus gemellatus*
			Adelphocoris	*Adelphocoris lineolatus*
		Aleyrodidae	*Bemisia*	*Bemisia tabaci*
			Trialeurodes	*Trialeurodes vaporariorum*
4	*Thysanoptera*	*Thripidae*	*Thrips*	*Thrips tabaci*
5	*Orthoptera*	*Gryllotalpidae*	*Gryllotalpa*	*Gryllotalpa gryllotalpa*
		Acrididae	*Locusta*	*Locusta migratoria*
			Calliptamus	*Calliptamus italicus*
			Dociostaurus	*Dociostaurus maroccanus*
			Schistocerca	*Schistocerca gregaria*
6	*Neuroptera*	*Chrysopidae*	*Chrysoperla*	*Chrysoperla carnea*
7	*Diptera*	*Syrphidae*	*Episyrphus*	*Episyrphus balteatus*
8	*Hymenoptera*	*Braconidae*	*Bracon*	*Bracon hebetor*
		Ichneumonidae	*Campoletis*	*Campoletis chlorideae*
9	*Mantodea*	*Mantidae*	*Mantis*	*Mantis religiosa*

Table.2 Distribution of the tomato entomofauna by orders

Order	Number of species	Share, %
Hemiptera	8	28.6
Lepidoptera	5	17.9
Orthoptera	5	17.9
Coleoptera	4	14.3
Hymenoptera	2	7.1
Neuroptera	1	3.6
Diptera	1	3.6
Thysanoptera	1	3.6
Mantodea	1	3.6
TOTAL	**28**	**100.0**

Table.3 Distribution of tomato agroecosystem insects across plant organs and soil layers

Order	Leaf	Stem	Flower	Fruit	Soil
Hemiptera	+++	++	+	–	–
Lepidoptera	++	++	+++	+++	+
Coleoptera	++	+	–	+	++
Thysanoptera	+++	+	++	+	–
Orthoptera	+	++	–	+	+++
Neuroptera	++	+	++	+	–
Diptera	++	–	++	+	–
Hymenoptera	++	+	++	+	–
Mantodea	+	++	+	+	–

Note: +++ – highly distributed; ++ – moderately distributed; + – rare; – – absent).

Table.4 Distribution of tomato entomofauna species by dominance groups

S.№	Species name	Family	Dominance group
1	*Aphis gossypii*	*Aphididae*	Dominant
2	*Bemisia tabaci*	*Aleyrodidae*	Dominant
3	*Helicoverpa armigera*	*Noctuidae*	Dominant
4	*Myzus persicae*	*Aphididae*	Subdominant
5	*Thrips tabaci*	*Thripidae*	Subdominant
6	*Agrotis segetum*	*Noctuidae*	Subdominant
7	*Trialeurodes vaporariorum*	*Aleyrodidae*	Subdominant
8	*Coccinella septempunctata*	*Coccinellidae*	Subdominant
9	*Hippodamia variegata*	*Coccinellidae*	Subdominant
10	*Chrysoperla carnea*	*Chrysopidae*	Subdominant
11-28	Remaining 18 species	Various families	Rare

Table.5 Monthly seasonal occurrence dynamics of major insect populations

Species name	April	May	June	July	August	September
Bemisia tabaci	+	++	+++	++++	++++	++
Aphis gossypii	++	+++	++++	++++	+++	+
Thrips tabaci	+	++	+++	++++	+++	++
Helicoverpa armigera	–	+	++	+++	+++	+
Tuta absoluta	–	+	++	++++	++++	++
Coccinella septempunctata	+	++	+++	+++	++	+
Chrysoperla carnea	+	++	+++	+++	++	+

(Note: – absent; + low; ++ moderate; +++ high; ++++ very high).

Discussion and Seasonal Dynamics Analysis

The impact of climatic factors on insect numbers and dynamics

The hot and dry summer climate of the Khorezm region significantly affects the phenological calendar of insects. The monthly monitoring data from 2023–2025 showed that the seasonal dynamics of the insect population correlate very closely with air temperature and plant phenology (Zaime & Gautier, 1989).

Observations showed that in April and May, due to relatively moderate air temperatures, the number of insects remains at a low and average level. In July and August-when air temperatures range between 28–35°C, the leaf surface area of the plant is maximally developed, and during the fruit-setting period-the density of all dominant pests (*Bemisia tabaci, Aphis gossypii, Helicoverpa armigera*) rises to the highest point (very high level) (Sharma *et al.,* 2020; Zhang *et al.,* 2022).

The population of beneficial entomophages (*Coccinella septempunctata, Chrysoperla carnea*) also reaches its highest peak in late June and July, proportionally to the increase in pest numbers (Pesenko, 1982). It was determined that the entomophage population reaches its maximum level approximately 10–15 days after the reproduction of the phytophage population (Zaime & Gautier, 1989). This clearly confirms the classic pest-entomophage delay correlation (biological control mechanism) in nature. Starting from mid-September, as a result of decreasing temperatures and the conclusion of the tomato vegetation, the population of all species drops sharply, and the insects begin transitioning into diapause preparation or overwintering phases.

Scientific rationale for planning the Integrated Pest Management (IPM) system

The obtained results on seasonal development and occurrence dynamics make it possible to formulate important recommendations for practical agriculture. Based on the analyses, it was determined that implementing pest control measures (chemical or biological treatments) in the tomato agroecosystem during the second half of May and early June provides the highest efficacy. Precisely during this period, aphid and whitefly populations are on the verge of rapid growth. Because the number of beneficial insects is still low during this period, applying selective (targeted) biological or chemical preparations causes minimal damage to natural entomophages and allows for their subsequent reproduction. Timely preventive and localized control measures conducted in May-June prevent massive outbreaks at the end of summer, which drastically reduces the use of pesticides throughout the general vegetation period (Rahimov *et al.,* 2021).

As a result of systematic research conducted in the tomato agroecosystems of the Khorezm region during 2023–2025, the following important scientific and practical conclusions were reached. In the tomato agroecosystem, 28 insect species belonging to 9 orders, 15 families, and 25 genera were identified. The majority of species belong to the orders *Hemiptera* (28.6%), *Lepidoptera* (17.9%), and *Orthoptera* (17.9%).

Aphis gossypii, Bemisia tabaci, and *Helicoverpa armigera* species were determined as the main dominant pests causing economic damage to tomato crops in the study area. The distribution of insects depends on the morphology of plant organs and feeding habits; it was proven that sucking phytophages are primarily active on the foliage, while noctuid moths damaging fruits and flowers are actively found on generative organs. Conversely, beneficial entomophages were observed accumulating in leaf layers with a high food source (pest density).

Insect activity is closely related to climatic factors, and it was identified that hot temperatures (28–35°C) in July-August create the most favorable conditions for the mass reproduction of dominant phytophages. To maintain biological balance and achieve stable yields in the tomato agrobiocenosis, the implementation of Integrated Pest Management (IPM) measures during the second half of May and early June is recommended as the scientifically most effective timeframe.

Author Contributions

Shaxlo A. Allabergenova: Investigation, formal analysis, writing—original draft.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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